APPLICATION UNDER UNITED STATES PATENT LAWS

Invention: **ADJUSTMENT OF PERIOD OF REAL-TIME SLOW DRIFT CORRECTION OF ALIGNMENT OF HANDSET'S LOCAL OSCILLATOR FOR A CORDLESS TELEPHONE**

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<u>This is a</u>:

[ ] Provisional Application

[ ] Regular Utility Application

[X] Continuing Application

[ ] PCT National Phase Application

[ ] Design Application

[ ] Reissue Application

[ ] Plant Application

SPECIFICATION

ADJUSTMENT OF PERIOD OF REAL-TIME SLOW DRIFT CORRECTION OF ALIGNMENT OF HANDSET'S LOCAL OSCILLATOR FOR A CORDLESS TELEPHONE

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates generally to cordless telephones. In particular, this invention relates to correction of a local oscillator of a remote handset in a cordless telephone.

2. Background of Related Art

Cordless telephones have gained in popularity over the years, and can now be found in many if not most homes or businesses. A cordless telephone is one in which the handset is not wired to its base unit, but instead uses wireless communication techniques between a remote handset and its base unit, typically allowing the remote handset to be used up to 1000 feet or more away from its base unit.

Fig. 11A illustrates a typical remote handset **800** of a digital cordless telephone.

The remote handset **800** includes a controller **805**, a coder-decoder (CODEC) **810**, a speaker **815**, a microphone **820**, a radio frequency (RF) transceiver **825**, a local oscillator **830**, an EEPROM **835**, a keypad **840**, a timing recovery circuit **845** and a program ROM **837**.

In the transmit direction, the microphone **820** outputs an analog signal to the CODEC **810**, which converts the microphone input signal to a digital microphone signal. As part of the conversion process, a clock signal is provided from the local oscillator **830** for the CODEC **810** to sample the microphone signal. The digital microphone signal is then passed to the RF transceiver **825** for encoding into a radio frequency (RF) signal for transmission to a complementary base unit. The controller **805** also retrieves frequency control information from the EEPROM 835 to

select the frequency that the RF transceiver **825** transmits. The program ROM **837** also provides a storage medium for the software that operates the remote handset **100** and for a security word.

In the receive direction, the RF transceiver **825** receives a RF signal from the complementary base unit. The RF transceiver **825** converts the RF signal to a digital signal that is passed to the CODEC **810** for decoding. The timing recovery circuit **845** provides correction information to the controller **805** to adjust the local oscillator **830** for the decoding of the digital signal. The output of the CODEC **810** is an analog signal for output by the speaker **815**.

Fig. 11B illustrates a base unit **850** of the digital cordless telephone. The base unit **850** contains circuitry which is complementary to that contained in the remote digital handset **800**, i.e., a complementary RF transceiver **870**, a controller **855**, a CODEC **860**, an EEPROM **880**, a program ROM **882**, a timing recovery circuit **885** and a local oscillator **875**. The base unit **850** also includes a telephone line interface **865** to interface with a public switched telephone network and a ring detect circuit **890** to detect the ring signal corresponding to an incoming telephone call.

For optimum performance between the remote handset **800** and the base unit **850**, both local oscillators, **830** and **875**, typically need to be frequency aligned. Preferably, the handset's local oscillator **830** typically needs to be frequency aligned with the base unit's local oscillator **875** to within 1 part per million (ppm) for reliable and noise-free communication.

A local oscillator may drift for a variety of reasons. A temperature change, a voltage change, or a tolerance variation in the components used in the digital cordless telephone may contribute to local oscillator drift.

There are several ways to correct for local oscillator drift. One method is called a coarse frequency search. A remote handset of a

cordless telephone in the coarse frequency search will adjust the remote handset's oscillator to within a range of 5 ppm from as far off as 300 ppm. The coarse frequency search may be performed at any time, but its purpose is to achieve frequency alignment to within about 5 ppm at best. A coarse frequency search is very time-consuming, e.g., 1-2 sec., and will drain the remote handset's battery if done while the cordless telephone is out of cradle.

Another method to correct for local oscillator drift is to use a synchronization bit(s) or frame. In a typical cordless telephone, a remote handset and a base unit communicate over the RF link using packets or frames. As part of the frame, several bits are reserved as synchronization bits. Fig. 12 illustrates a typical frame **900** used in communication between a remote handset and a base unit including a synchronization field.

As shown in Fig. 12, the frame **900** includes a data field **910**, error correction code ("ECC") field **920** and a synchronization field **920**. Each respective field includes a number of bits. The number of bits per field is dependent on the functionality of the field.

The data field **910** of the frame **900** typically contains the encoded voice signals.

The ECC field **920** of the frame **900** typically contains the error correction code for the data field **910**. As the voice signals are encoded, typically, an error correction code is included in the frame **900** to ensure that the voice signals are properly transmitted and received.

The synchronization field **930** provides a method for a remote handset and base unit to frequency align by using the synchronization field to correct the receiving local oscillator or to derive a clock signal.

Although this method is effective, the synchronization field technique requires time for the receiving remote handset or base unit to

frequency align. Moreover, this synchronization time may introduce unwanted delays in the communications between the base unit and the remote handset.

There is a need for an improved method and/or apparatus to frequency align a remote handset's local oscillator with a base unit's local oscillator to a high degree, e.g., to within 1 ppm for reliable and noise free communication.

SUMMARY OF THE INVENTION

In accordance with the principles of the present invention, a link verification controller for a wireless device comprises a default link verify period setting to establish a first period for a link verification operation between a remote device and a matching base unit during normal operations. A controller adjusts the established first period for the link verification based on a status of a battery of the remote device.

A method of determining a period for an operation between a remote unit and a matching base unit in accordance with another aspect of the present invention comprises detecting a charging to a remote handset from a base unit. A period is adjusted between a check of frequency alignment between the remote handset and the base unit based on a battery voltage level in the remote handset.

BRIEF DESCRIPTION OF THE DRAWINGS

Features and advantages of the present invention will become apparent to those skilled in the art from the following description with reference to the drawings, in which:

Fig. 1A illustrates a block diagram of a remote handset of a digital cordless telephone implementing a real-time drift correction of a local oscillator.

Fig. 1B illustrates a block diagram of a base unit of a digital cordless telephone implementing a real-time drift correction of a local oscillator of the remote handset of Fig. 1A.

Fig. 2 illustrates an exemplary high-level flow diagram of a real-time drift correction of a local oscillator for a remote handset.

Fig. 3 illustrates an exemplary flow diagram of the frequency alignment phase of the real-time drift correction of a local oscillator in Fig. 2.

Fig. 4A illustrates a timing diagram of a timing recovery state for a frequency aligned remote handset oscillator.

Fig. 4B illustrates a timing diagram of a timing recovery state for a drifted remote handset oscillator.

Fig. 5 shows an exemplary flow diagram of a remote handset standby function.

Fig. 6 shows an exemplary flow diagram of an initial part of a TDD mode of a remote handset.

Fig. 7 shows a flow diagram of the concluding part of the TDD mode illustrated in Fig. 6.

Fig. 8 shows the extension of the embodiment of Fig. 1 to include a maximum link verify period setting (i.e., least frequent) and a minimum link verify period setting (i.e., most frequent).

Fig. 9 is a flow chart showing an exemplary adjustment of the link verify period using a fixed period when the remote handset is remote from the base unit and using an adjustable period based on the voltage of the battery when the remote handset is cradled in the base unit, in accordance with another aspect of the present invention.

Fig. 10 is a flow chart showing an exemplary adjustment of the link verify period using a fixed period when the remote handset is remote from the base unit, suspending the link verification operations (and

thus frequency alignment operations) when the remote handset is in a quick charge mode, and using an adjustable period based on the voltage of the battery when the remote handset is cradled in the base unit, e.g., when receiving a trickle charge or no charge, in accordance with yet another aspect of the present invention.

Fig. 11A shows a block diagram of a conventional remote handset of a digital cordless telephone.

Fig. 11B shows a block diagram of a conventional base unit of a digital cordless telephone.

Fig. 12 shows a conventional frame with a synchronization field used in an RF link between a remote handset and a base unit of a digital cordless telephone.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

The present invention frequency aligns a local oscillator of a remote handset with a local oscillator of a base unit in a digital cordless telephone.

In particular, the present invention provides for a periodic fine adjustment at regular intervals of a remote handset's local oscillator while the remote handset is in its standby (sniff) mode. Advantageously, the frequency alignment operation can take less than 400 ms every minute, and thus will not interfere with the normal operations of the digital cordless telephone, while continuously maintaining frequency alignment.

Alternatively, link verification may be done less frequently based on oscillator drift characteristics under assumed temperature and voltage conditions. A longer link verification duration, e.g., 15 minutes, may exist and allow for greater times between scheduled verifications, particularly in lower power applications.

The real-time drift correction of a remote handset's local oscillator, in accordance with the principles of the present invention,

begins with the remote handset in a standby (sleep sniff) mode. The remote handset periodically awakens from a sleep mode, e.g., every fifteen minutes (or some other predetermined interval) and goes into a normal link verification mode.

Once in the link verification mode, the remote handset enters a time division duplexing (TDD) mode and attempts to establish a link with the base unit.

After the remote handset establishes a link with the base unit, the remote handset requests a security word from the base unit. Upon receiving the requested security word, the remote handset determines if the requested security word matches the security word of the remote handset. During this exchange of commands between the remote handset and the base unit, the remote handset continuously adjusts its local oscillator to achieve frequency alignment within, e.g., 1 part per million (ppm) to the frequency of the local oscillator of the base unit. Alternatively, frequency alignment may be achieved within a user-specified ppm value.

The remote handset achieves frequency alignment during the command exchange by implementing a software frequency adjustment of its local oscillator in a controller of the remote handset. Since a command occupies a frame, the controller of the remote handset enters a timing recovery state once during the frame where the current timing of the frame is compared with a previous timing. When a cumulative timing slip is greater than a designated threshold, a frequency adjustment is made. Thus, frequency alignment is achieved in a rapid fashion.

Fig. 1A is an illustration of an embodiment of a remote handset **100** of a digital cordless telephone implementing a real-time slow drift correction of a local oscillator.

In particular, Fig. 1A shows a block diagram of a remote handset **100** implementing a real time slow drift correction of a local oscillator. The remote handset **100** includes a controller **105**, a coder-decoder (CODEC) **110**, a speaker **115**, a microphone **120**, a radio-frequency (RF) transceiver **125**, a local oscillator **130**, an EEPROM **135**, a program ROM **137**, a keypad **140**, an alignment control **197**, a battery **971**, and a link verify period setting **972**,

The controller **105** may be a digital signal processor (DSP), microprocessor, microcontroller, or combinational logic. The controller **105** provides an execution platform to execute a suitable software program to operate the remote handset **100**.

The CODEC **110** provides a way to convert between analog voice signals and digital voice signals. The CODEC **110** is an electronic device that converts analog voice signals to digital voice signals via an analog-to-digital converter. Also, the CODEC **110** converts received digital voice signals to analog voice signals via a digital-to-analog converter.

The CODEC **110** converts between the analog and digital signals based on a clock signal provided by the local oscillator **130**. The local oscillator **130** may be a voltage-controlled oscillator ("VCO") where a control voltage may alter the output frequency of the local oscillator **130** by the alignment control **197** under the control of the controller **105**.

The microphone **120** provides a way for the user to input voice signals into the remote handset **100**.

The speaker **115** provides a way for the user to hear the output voice signals from the remote handset **100**.

The RF transceiver **125** provides an RF interface between the remote handset **100** and a complementary base unit. The remote handset **100** relays voice signals between a base unit via an RF link. The

RF transceiver **125** provides a conversion between RF signals and the digitized voice signals.

The program ROM **137** provides a storage medium to store software that operates the remote handset **100**. The EEPROM **135** stores frequency control information such as a digital-to-analog converted (DAC) value of the frequency, and a security word. The DAC value is used to control the frequency of the local oscillator **130** of the remote handset. The security word is used during exchanges between an exclusively matched set of, e.g., a remote handset and its base unit.

The keypad **140** provides a way for the user to operate the digital cordless telephone.

The battery **971** provides power to the remote handset **100**.

The link verify period setting timer **972** provides a way to program how often the remote handset **100** corrects the drift of its local oscillator **130**.

In the transmit direction, the microphone **120** outputs an analog signal to the CODEC **110**, which converts the microphone input signal to a digital microphone signal. The digital microphone signal is input to the RF transceiver **125** for encoding into a digital signal for transmission to a complementary base unit. The controller **105** directs the output from the local oscillator **130** to encode the digital microphone signal. The controller **105** also retrieves frequency control information from the EEPROM **135** to select the frequency that the RF transceiver **125** transmits.

In the receive direction, an RF transceiver **125** receives an RF signal from the complementary base unit. The RF transceiver **125** converts the received signal to a digital signal that is then passed to the CODEC **110** for decoding. The local oscillator **130** provides a clock signal via the controller **105** to the CODEC **110**. The output of the CODEC **110** is an analog voice signal for output by the speaker **115**.

Fig. 1B illustrates a base unit **150** of the digital cordless telephone. The base unit **150** contains circuitry which is complementary to that contained in the remote handset **100**, i.e., a complementary RF transceiver **170**, a controller **155**, a CODEC **160**, an EEPROM **180**, a program ROM **182** and a local oscillator **175**. The base unit **150** also includes a telephone line interface **165** to interface with a public switched telephone network. A ring detect circuit **190** detects the ring voltage relating to an incoming telephone call.

Fig. 2 shows an embodiment of a real-time slow drift correction of a local oscillator **130** used in the remote handset **100** of the digital cordless telephone such as that shown in Fig. 1A.

In particular, Fig. 2A shows an example of a software state module **200** affected by the real-time slow drift correction of the local oscillator **130** implemented by the controller **105** of the remote handset **100** shown in Fig. 1A.

In step **210**, the controller **105** places the remote handset **100** in a sniff mode. The sniff mode is a standby mode of operation for the remote handset **100**. While in the sniff mode, the remote handset **100** is able to conserve power while monitoring the RF link for incoming transmissions from the base unit **150**.

Periodically, the controller **105** of the remote handset **100** disengages from a sleep sniff or standby mode that conserves battery life to begin a normal link verification, as shown in step **220**. The controller **105** may initiate the normal link verification at a pre-determined interval such as every one-minute or other pre-defined interval.

Once in the normal link verification, the remote handset **100** enters into a time domain duplex (TDD) mode, as shown in step **230**.

Once in the TDD mode **230**, the remote handset **100** attempts to establish an RF link with the base unit **150**, as shown in step **240**. The local oscillator **130** of the remote handset **100** is controlled by a

DAC value written by the controller **105**. The controller **105** retrieves the last used DAC value relating to the frequency timing from the EEPROM **135**, and subsequently initiates a link verification. The last used DAC value is stored in the EEPROM **135** prior to entering the sniff mode or exiting TDD mode.

Step **250** shows the frequency alignment phase. After the RF link is established, the remote handset **100** requests a unique security word from the base unit **150**. After the unique security word is received by the remote handset **100**, the controller **105** determines if the received security word matches the remote handset security word. During this exchange of commands, the controller **105** of the remote handset **100** continuously adjusts its local oscillator **130** to achieve frequency alignment within 1ppm (or some predefined ppm).

If, from step **250**, the requested security word matches, the RF link is verified as shown in step **260**. In this case, the controller **105** of the remote handset **100** sets a **LINK_VERIFY_NORM_SUCCESS** flag. The controller **105** then returns the remote handset **100** back to its sniff mode.

If, from step **250**, the requested security word does not match, the link is deemed to be not verified, as shown in step **270**. In this case, the controller **105** of the remote handset **100** sets a **LINK_VERIFY_NORM_FAIL** flag. The controller **105** then sends a "link verify fail message" to the base unit **150** and returns the remote handset **100** back to its sniff mode.

The controller **105** of the remote handset **100** may set the **LINK_VERIFY_NORM_FAIL** flag if the base unit **150** fails to send the requested security word or acknowledges the remote handset **100** request for the security word after a predetermined time-out period.

One aspect of the present invention is the correction of a local oscillator **130** to achieve frequency alignment without the use of a

specific circuit. Instead, the frequency correction of the local oscillator **130** is accomplished using a software module implemented by the controller **105**.

Fig. 3 is a more detailed flow diagram of the frequency alignment phase **250** of the real time slow drift correction of the alignment of the local oscillator **130** of the remote handset **100** shown in Fig. 2, in accordance with the principles of the present invention.

Within the frequency alignment phase, step **250**, there is an exchange of commands that allows the local oscillator **130** of the remote handset **100** to frequency align. In typical digital cordless telephones, the commands that are exchanged are predetermined fixed size frames.

Once the controller **105** of the remote handset **100** is in the frequency alignment phase **250**, the controller **105** enters into a timing recovery state, as shown in step **300**, upon receiving a command from the base unit **150**.

Upon receipt of the command, the controller **105** of the remote handset **100** reads the current timing state of the received frame, as shown in step **310**.

In step **320**, the current timing state of the received frame is compared with a previous timing state.

In step **330**, if the timing difference or slip between the timing states is greater than a predetermined threshold, the controller **105** of the remote handset **100** adjusts the local oscillator **130**, as shown in step **340**. Alternatively, a series of comparisons may be implemented to tally a cumulative timing slip to be compared against the predetermined threshold.

Otherwise, the controller **105** of the remote handset **100** does not adjust the local oscillator **130**, as shown in step **350**. Subsequently, returning to Fig. 2, the controller **105** finishes the frequency alignment phase **250**, and proceeds to step **260** or step **270**.

Fig. 4A better illustrates the timing recovery state **300** of Fig. 3 in a timing diagram showing a base unit oscillator, a data frame, and a remote handset oscillator during a previous read operation.

In particular, a base unit oscillator output is represented by a base unit clock signal **400** as shown in waveform (1).

A data frame **410** represents a command as shown in waveform (2). The command is a fixed predetermined size.

A remote handset oscillator is represented by a remote handset clock signal **420** as shown in waveform (3).

When the base unit **150** transmits a command to the remote handset **100**, the command (waveform (2)) is transmitted frequency aligned with the base unit clock signal **400** as shown in waveform (1).

When the remote handset **100** receives the command, the remote handset **100** enters into the timing recovery state **430** as shown in waveform (3). In the timing recovery state **430**, the remote handset **100** is able to determine the timing of the command based on the remote handset clock signal **420** as shown in waveform (3).

The controller **105** of the remote handset **100** may determine timing using various techniques. For example, the controller **105** may count the zero crossings in the data frame **410** or monitor a sub-symbol clock counter at the end of the data frame **410**. Since the timing recovery state **430** is a fixed amount of time, the timing of the data frame **410** may be easily derived.

Subsequently, the value of the timing of the command is retained to be compared against the next incoming command.

Fig. 4B illustrates a timing diagram of a base unit oscillator (waveform (1)), a data frame (waveform (2)), and a remote unit oscillator (waveform (3)) of a next incoming command when the remote unit oscillator **130** has drifted from the base unit oscillator **175**.

As illustrated in Fig. 4B, the base unit oscillator is represented by the base unit clock signal **440** as shown in waveform (1). The command is represented as a data frame **450** as shown in waveform (2). The remote handset oscillator is represented by the remote unit clock signal **460** as shown in waveform (3).

As with Fig. 4A, a command is shown in waveform (3) as having been transmitted by the base unit **150** as a next frame **450** based on the base unit clock signal **440** as shown in waveform (1). However, in this event, the remote handset clock signal **460**, shown in waveform (3) has drifted by the slip amount **480**.

When the controller **105** of the remote handset **100** enters a timing recovery state **470**, shown in waveform (3), the controller **105** determines the timing of the next frame **450**. Since the remote handset clock signal **460** has drifted, the timing value of the next frame **450** differs by the value of the slip **480**.

If the difference between the two commands is greater than some predetermined threshold, the local oscillator **130** of remote handset **100** may be adjusted. Alternatively, the differences between several received frames may be totaled and compared against a threshold to determine from an average or accumulated value whether or not the local oscillator **130** of the remote handset **100** needs to be adjusted.

Fig. 5 illustrates a high level flow diagram of a normal link verification phase **220** (Fig. 2) used to implement the real-time slow drift correction in the remote handset of Fig. 1A.

In step **510**, while the remote handset **100** is in sniff mode, the controller **105** of the remote handset **100** determines whether or not the link verify period setting timer **972** has elapsed. The link verify period setting timer **972** may be conveniently set to once every minute, hour, etc.

If the link verify period setting timer **972** has not elapsed, the controller **105** of the remote handset **100** returns to the beginning.

Otherwise, the controller **105** sets the flag, **LINK_VERIFY_NORM_ACTIVE**, as shown in step **520**. Then, the controller **105** requests to enter a time division duplexing (TDD) mode.

After the controller **105** of the remote handset **100** returns from the TDD mode, the controller **105** clears the flag, e.g., **TIMER0_LINK_VERIFY_FIRED**, as shown in step **530**.

Subsequently, the controller **105** exits the normal link verification phase **220** and the controller **105** returns to its sniff mode, as shown in step **540**.

Fig. 6 illustrates an exemplary flow diagram of the initial part of the TDD mode **230** shown in Fig. 2.

In particular, after the controller **105** of the remote handset **100** enters the TDD mode **230**, the controller **105** checks to see if the **LINK_VERIFY_NORM_ACTIVE** flag has been set, as shown in step **610**. If the **LINK_VERIFY_NORM_ACTIVE** flag has not been set, the controller **105** exits out of the TDD mode **230**. Otherwise, the controller **105** moves to step **615**.

In step **615**, the controller **105** of the remote handset **100** is placed into an acquire state in order for the remote handset **100** to acquire the base unit **150**. The controller **155** in the base unit **150**, also in sniff mode, wakes up to respond to the remote handset **100**. Otherwise, if the controller **105** of the remote handset **100** is not placed into the acquire state, the controller **105** exits the TDD mode **230**.

Once the remote handset **100** sees the base unit **150**, the controller **105** of the remote handset **100** requests a security word from the base unit **150** by sending a suitable command, e.g., command **CMD_2F**, as shown in step **620**.

In response to the received security word from the base unit **150**, the controller **105** of the remote handset **100** sends an acknowledgment ACK to the base unit **150**, as shown in step **625**. In this

embodiment, the RF command exchange is 8 bits, but the RF command may be any designated length. Since, in this embodiment, the RF command exchange is 8 bits, the base unit **150** would first send the lower byte followed by the upper byte of the security word in response to receiving the **CMD_2F**, or other designated command from the remote handset **100**. The base unit **150** sends the upper byte of the security word in response to an **ACK** from the remote handset **100** receiving the lower byte.

In step **630**, after the upper byte of the security word is received by the remote handset **100**, the controller **105** compares the transmitted security word with the security word stored in the EEPROM **135**, and a match is determined in step **635**.

In step **640**, if there is a match in the security word, the controller **105** of the remote handset **100** transmits a link verify command (e.g., **CMD_28**) or other designated command, to the base unit **150**. The **CMD_28**, or other designated command, represents that the link has been verified.

A flag, e.g., **SECURITY_WORD_VERIFIED**, is set in a security state called **SECURITY_VERIFIED_STATE**, as shown in step **645**.

In step **650**, the controller **105** of the remote handset **100** waits for another **ACK** from the base unit **150** based on a set timer. The controller **105** will exit out of the TDD mode **230** if the base unit **150** fails to respond before the expiration of the timer.

Returning to step **635**, if there is not a match, the controller **105** of the remote handset **100** transmits a **CMD_29**, or other designated command, to the base unit **150**, as shown in step **655**. The **CMD_29**, or other designated command, represents that the link has not been verified.

In step **660**, the controller **105** sets a flag, e.g., **SECURITY_WORD_NO_MATCH**, while the controller **105** is in a security state, e.g., **SECURITY_VERIFY_STATE**.

In step **670**, the controller **105** of the remote handset **100** sets a flag, e.g., **LINK_VERIFY_NORM_FAIL**.

Subsequently, as shown in step **680**, a timer, e.g., **phone_countdown**, is initialized by the controller **105** of the remote handset **100** to a value of, e.g., 100, preferably corresponding to the number of RF frames. The timer in this embodiment is set to expire after approximately 500 msec.

The controller **105** of the remote handset **100** then returns to step **650** for further processing.

Fig. 7 represents an exemplary flow diagram of the latter part of the TDD mode **230** in Fig. 2.

After step **650** of Fig. 6, the controller **105** of the remote handset **100** determines if the **LINK_VERIFY_ACTIVE** flag has been set and the controller **105** is waiting for an **ACK** from the base unit **150** from the match/no-match determination of the security word, as shown in step **710** of Fig. 7.

If the two conditions are met, the controller **105** of the remote handset **100** then determines whether or not there was a match, and whether or not the **ACK** has been received or a time-out has occurred, as shown in step **720**.

If there was a match and the **ACK** has been received or a time-out has occurred, the controller **105** sets a **LINK_VERIFY_NORM_SUCCESS** flag, as shown in step **730**.

In step **740**, the controller **105** of the remote handset **100** clears the **LINK_VERIFY_NORM_ACTIVE** flag and subsequently exits the TDD mode **230**, as shown in step **770**.

Returning to step **710**, if the two conditions are met, the controller **105** of the remote handset **100** determines whether or not there has been a no-match determination and an **ACK** has not been received, or a time-out has occurred, as shown in step **750**.

If there has been a no-match, no **ACK**, or the time-out determination from step **750**, the controller **105** then sets a **LINK_VERIFY_NORM_FAIL** flag, as shown in step **760**. The controller **105** of the remote handset **100** then returns to step **740**.

The objective of this periodic link verification is to allow the remote handset to run for a time sufficiently long enough to track the slow drift of its local oscillator with respect to the base unit since the last correction was made. The last correction may have occurred during either a link verification or a normal traffic link. If the handset does not establish a link with the base unit within the time-out period (e.g., 400 or 800 msec), then the handset flags that condition as a link verification fail, **LINK_VERIFY_NORM_FAIL**. If the system fails to start up within 400 msec of establishing the link, that is also considered a link verification fail. Upon failure, coarse frequency alignment can be performed.

Thus, in accordance with the principles of the present invention, measure of a timing slip between frames of a time division communication from the base unit to the remote handset of a cordless telephone (or other wireless device) is used as a basis for correcting the frequency of a local oscillator in the remote handset to be aligned with the timing of the matching unit, i.e., the base unit. Moreover, in the disclosed embodiment, the frequency alignment was performed on a periodic basis, e.g., every minute, utilizing the communications during a sniff mode as the data frame for comparison to a previously measuring timing to determine if an excessive amount of slip has occurred.

In accordance with another aspect of the present invention the timed instantiation of the frequency alignment procedure can be

adjusted to conserve power of the remote handset **100**, particularly when the remote handset **100** is being charged by the base unit **150**. This will enable the reduction of the overall power requirements of the cordless telephone, particularly when power consumption is at its highest during a "quick charge" operation of the battery **971** in the remote handset **100**. Reduction of the maximum power requirements of the cordless telephone enables the use of a smaller and less expensive AC to DC charger, lower heat buildup in the cordless telephone, and other benefits of a lower power device.

In particular, the period of the link verify operation in the earlier embodiments is preferably set to account for the worst case situation causing misalignment in the frequency between the remote handset **100** and the base unit **150**, e.g., worst case changes in temperature and battery voltage in the remote handset **100**. However, since the remote handset **100** is often kept in the same location as the base unit **150**, temperature changes may not be a significant factor causing misalignment of the frequency. This is particularly true when the remote handset **100** is being charged by the base unit **150**.

In such a case, the period between link verify operations can be lengthened without detrimentally affecting performance of the cordless telephone. For instance, when the remote handset **100** is detected as being cradled by the base unit **150** (e.g., when being charged), affects due to differences in temperature between the remote handset **100** and the base unit may effectively be ruled out. This leaves only a difference in voltage level as a significantly contributing factor to a drift of the local oscillator in the remote handset **100**.

In accordance with this aspect of the present invention, the voltage level of the battery **971** in the remote handset **100** can be measured and used as a basis in determining a tolerance in how often

frequency alignment should be performed between the remote handset **100** and the base unit **150**.

Initially when a remote handset **100** is cradled, and/or at all times when the remote handset **100** is not cradled (and therefore remote from the base unit **150**), the link verify period can be set to accommodate the worst case scenario for frequency misalignment. Thus, the link verify period can be set to its most frequent setting. Then, as the voltage level of the battery **971** in the remote handset **100** increases under a "quick charge" or similar operation (indicating a more fully charged battery) the period between link verify operations can be lengthened. Lengthening of the link verify operations will not detrimentally affect frequency alignment as the voltage level of the battery **971** increases because the commensurate affects on the local oscillator **130** will likewise improve.

Thus, in the disclosed embodiment, when the remote handset **100** is being charged (particularly at a "quick charge" high current level), the link verify period would not be set to a fixed time period but would instead be based on a voltage level of the battery **971**.

The desired minimum interval between link verify operations (and thus TDD based frequency alignment operations) can be determined empirically based on, e.g., laboratory measurements, and set by the factory in the cordless telephone. Alternatively, the desired intervals between frequency alignment operations can be based on historical operation of a particular cordless telephone and automatically adjusted by the controller **105** on an on-going basis. As the link verify period increases, power consumption by the cordless telephone will be reduced.

In accordance with the principles of this aspect of the present invention, it is preferred that a minimum link verify period also be established to ensure that frequency alignment occasionally takes place even with a fully charged battery **971** in the remote handset **100**.

A specific example is provided showing a design combining both voltage-based and scheduled interval-based link verify periods.

In particular, a link verify period can be set to be a most frequent setting level, e.g., once every 10 minutes, when the battery **971** is deemed to be fully charged (i.e., at its maximum voltage level). When the battery **971** is fully charged, the battery **971** draws minimal if any power, and thus the overall power budget can easily accommodate a more frequent link verify operation allowing more frequent frequency alignment operations.

However, if the voltage level of the battery **971** is fully discharged, the full capability of the AC to DC power converter may be required, and power usage in the cordless telephone may be at its greatest. Thus, to help conserve use of power when conservation is most important, the link verify period can be set to its least frequent level, e.g., once every hour.

Then, as the battery **971** becomes charged and the power draw is reduced, more frequent link verify periods can be accommodated within the power budget.

Fig. 8 shows the extension of the embodiment of Fig. 1 to include a maximum link verify period setting **972a** (i.e., least frequent) and a minimum link verify period setting **972b** (i.e., most frequent).

In particular, rather than a fixed link verify period setting **972** as shown in Fig. 1, a maximum and minimum value for the link verify period may be established, with the minimum link verify period setting **972b** serving as the "default" link verify period when, e.g., the remote handset **100** is remote from the base unit **150**.

Fig. 9 is a flow chart showing an exemplary adjustment of the link verify period using a fixed period when the remote handset **100** is remote from the base unit **150** and using an adjustable period based on

the voltage of the battery **971** when the remote handset **100** is cradled in the base unit **150**.

In particular, in step **891** of Fig. 9, the remote handset **100** determines if it is cradled and receiving a charge to its battery **971**. Alternatively, the base unit **150** can determine if the remote handset **100** is cradled and receiving a charge and communicate that information to the remote handset **100** over the wireless communications between the two.

In step **893**, if the remote handset **100** is not cradled, a default link verify period (e.g., the most frequent period accommodating the worst case scenario) is used.

However, if the remote handset **100** is cradled, the voltage of the battery **971** in the remote handset **100** is measured, as shown in step **895**.

In step **897**, the period of the link verify operations (and thus of the frequency alignment operations) is adjusted based on the current voltage of the battery **971** measured in step **895**.

It is also within the principles of the present invention to extend or even suspend the link verification process (and thus frequency alignment) altogether at desired times, e.g., when the remote handset **100** is in a quick charge mode, since during this mode the cordless telephone is likely at or near its maximum power draw. Thereafter, when the quick charge level is turned off and, e.g., a trickle charge current level is being provided to the battery **971**, the adjustable link verification period can again be set to be based on a voltage level of the battery **971**.

For instance, Fig. 10 is a flow chart showing an exemplary adjustment of the link verify period using a fixed period when the remote handset **100** is remote from the base unit **150**, suspending the link verification operations (and thus frequency alignment operations) when the remote handset **100** is in a quick charge mode, and using an adjustable period based on the voltage of the battery **971** when the

remote handset **100** is cradled in the base unit **150**, e.g., when receiving a trickle charge or no charge.

In particular, in step **961** of Fig. 10, either the remote handset **100** and/or the base unit **150** determines whether or not the remote handset **100** is cradled in the base unit **150**.

In step **962**, if the remote handset **100** is not cradled, the default link verify period is used.

However, if the remote handset **100** is cradled, a further determination is made as to whether or not the remote handset **100** is receiving the high current quick charge or not, as shown in step **963**.

If the remote handset **100** is in a quick charge mode, then the link verify operations (and thus the frequency alignment operations) are suspended altogether in step **966**. Once the battery **971** is charged sufficient for the remote handset **100** to exit the quick charge mode (e.g., to enter a trickle charge mode), the link verify operations can be re-enabled by re-determination of step **963**.

If the remote handset **100** is not in a quick charge mode, then the voltage of the battery **971** is measured in step **964**, and the link verify period is adjusted based on the measured battery voltage level, as shown in step **965**.

While the invention has been described with reference to the exemplary embodiments thereof, those skilled in the art will be able to make various modifications to the described embodiments of the invention without departing from the true spirit and scope of the invention.